THE

# SANITARY MANAGEMENT AND UTILISATION

OF

# SEWAGE.

LONDON
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A TREATISE ON THE

# SANITARY MANAGEMENT AND UTILISATION

OF

# SEWAGE:

COMPRISING DETAILS OF A SYSTEM APPLICABLE TO COTTAGES, DWELLING-HOUSES, PUBLIC BUILDINGS, AND TOWNS; SUGGESTIONS RELATING TO THE ARTERIAL DRAINAGE OF THE COUNTRY AND THE WATER SUPPLY OF RIVERS.

BY

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*ILLUSTRATED WITH NUMEROUS DRAWINGS.*

LONDON:
LONGMAN, GREEN, LONGMAN, ROBERTS, & GREEN.
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# PREFACE.

THE SYSTEM for the management and utilisation of sewage recommended in the following pages has been to me a matter of long and serious study.

I have made many experiments during the fifteen years that the Crown Property at Windsor has been under my care; while, in the last few years of his life, I had frequent opportunities of hearing the Prince Consort express his views on the subject, to which he had given his earnest attention.

The first place at which I successfully carried out plans for the utilisation of sewage was Wellington College, in 1859; and the Prince, as President, was satisfied with the result. In 1862 Lord Derby, who had succeeded His Royal Highness as President, re-

quested me to prepare a statement of the principles upon which the works at the College had been executed; and at a public meeting at Halifax, in the autumn of the same year, his Lordship recommended to the favourable notice of the public the pamphlet which I had prepared and printed at his suggestion.

So important, indeed, was the subject in Lord Derby's judgment, that he offered a premium of £200 to anyone who would successfully utilise the sewage of a town of 5,000 inhabitants. About the same time Mr. Gladstone insisted strongly on the need of some satisfactory method of dealing with a national subject so important but so little understood.

From that time I have incessantly studied the question, as I felt bound, if I could, to follow up to their legitimate conclusions many of the principles which were laid down as essential by Lord Derby, and for the correctness of which I felt that I was to a certain extent answerable.

I may remark that all my plans have been put

into practice in detail, some in one place and some in another. The only exception to this statement will be found in the 5th Chapter, on the "Drainage of Towns." No town has, to my knowledge, yet been drained on the system which I have recommended, and which I believe to be the only correct one.

I have been much encouraged and assisted by the Hon. Charles Gore, the Commissioner of Woods, under whom I am placed, through his having facilitated my inquiries by every means in his power, and allowed me to pursue my investigations on the Crown Property.

To Sir James Clark, Bart., I am indebted for some suggestions on the sanitary aspect of the subject.

To Sir William Hayter, Bart., as Chairman of the Council of the Broadmoor Criminal Lunatic Asylum, near Wokingham, I am indebted for the first opportunity of carrying out the whole of my plans, which in 1865 will be seen there in full operation.

Many details for constructing filters, and similar parts of the scheme, especially those on page 12, have been worked out with much skill and ingenuity by Mr. Morris, Clerk of Works in Windsor Park.

My descriptions, with the assistance of these drawings, are, I hope, so clear that all may understand, and, if they think fit, carry out the same plans elsewhere.

My original intention in writing a detailed description of the principles upon which alone I believe sewage can be managed, was to save myself the trouble of being constantly called upon to explain them. The importance of the question now induces me to lay the whole before the public, so that the wide field may be occupied by the simultaneous efforts of many engineers.

Much remains as yet undiscovered. Probably a great portion of what is contained in these pages is well known to sanitary engineers; but I am nevertheless induced to deal with the whole subject for the sake of completeness.

If I have been successful in leading the way a few steps farther than anyone has yet gone, and enabling those who have seen what has already been done to understand not only the principles on which I have

acted but the reason why so many schemes have failed, I shall be fully satisfied.

Since I commenced putting consecutively on paper my views on the utilisation and management of sewage, the Committee appointed last session by the House of Commons to investigate the different schemes proposed for the disposal of the sewage of the metropolis have issued their Report. On perusing that valuable document, I do not see reason for altering any of the conclusions at which I had previously arrived; I have therefore referred but very slightly to it. All the difficulties of the subject are stated in that report very strongly. My great hope is that while I have pointed these out from my own judgment and experience, I have also been able to show the method of overcoming most of them.

I have attempted to treat the matter not so much in a professional style as in one that will be understood by any educated person who devotes a little time to the perusal of this book.

I must, in conclusion, acknowledge my obligation

to Mr. Woodward, Her Majesty's Librarian, for the assistance he has given me in preparing this work for the press.

WM. MENZIES.

PARKSIDE:
*15th December* 1864.

# CONTENTS.

## CHAPTER I.

### THE VARIOUS METHODS OF MANAGING SEWAGE.



## CHAPTER II.

### THE SANITARY CONSTRUCTION OF HOUSE DRAINS AND CLOSETS.



## CHAPTER III.

### THE PREPARATION OF SEWAGE FOR IRRIGATION.

## CHAPTER IV.

### METHODS OF IRRIGATION.



## CHAPTER V.

### THE DRAINAGE OF TOWNS.

## CHAPTER VI.

### THE ARTERIAL DRAINAGE OF THE COUNTRY.



## CHAPTER VII.

### GENERAL SUMMARY.

# LIST

OF

# ILLUSTRATIONS.

THE

# MANAGEMENT AND UTILIZATION

OF

# SEWAGE.

## CHAPTER I.

### THE VARIOUS METHODS OF MANAGING SEWAGE.

It can scarcely be necessary to say much on the importance of the subjects which I have undertaken to treat. Every member of the community is more or less interested in them; while there is a large class whose daily business it is to construct houses and drains, and deal with the difficulties attending the management of sewage.

Both in a sanitary and an economical light the whole forms one of those questions which the efforts of engineers have hitherto by no means succeeded in solving. Many have dealt with the subject solely in its sanitary aspects, and confined their attention to the carrying out of such works as would place

the inmates of any building or town in a healthy atmosphere; while some have spent much labour in devising the best sizes and forms of drains, and others have looked upon it as an agricultural operation, discussing simply the best means of making profit by applying sewage to land, and converting its qualities to some beneficial purpose.

Until these branches of the subject are taken together, no satisfactory result can be obtained.

It is my wish now so to unite them as they ought and eventually must be, for I am fully convinced that perfect harmony will be found to exist when we have discovered for every detail the best methods of treatment.

The principles advocated in the 5th Chapter, on the Sewage and Drainage of Towns, seem to me to follow from the conclusions forced upon me principally from my experience of large buildings.

The laws of this country are very stringent (and rightly so) on the subject of nuisances arising from sewage, and they must tend more in the same direction as population increases.

At present, if anyone should purchase a piece of ground, and build a house upon it, he may drain his fields on agricultural principles, and send down the land-water or the rain-water off his house to lands

lying below the level of his own, in the direction in which the surface-water previously flowed, provided no injury arises from the new and more concentrated form in which the water comes.

On the important question which here arises as to the effect of Land Drainage on the streams of the country, I shall speak more fully in the 6th Chapter, on Arterial Drainage.

A proprietor cannot, however, send down the sewage from his house without consent of the owner of the lower land.

And, again, if a small house had existed upon the upper land, and its sewage had flowed down upon the lower, the owner of the first could not build a much larger house on the same spot, so as to send down a greater flow than he had discharged formerly.

If the owner of the lower land fail to protest against any sewage thus being sent down upon him, and allow the owner of the higher land to acquire a right, which he would do in process of time, probably twenty years, the arrangement cannot then be disturbed, and the lower land is diminished in value for building ground for all future time; and, indeed, its value for any other purposes than irrigation is immensely depreciated. Anyone, therefore, who can prove an injury of this class can proceed against the owner of the newly-

built house for a nuisance; and as this may be done at any time within twenty years after the house has been built, perhaps at the cost of thousands, the owner should take care, at the first, that he does not lay himself or his successors open to these proceedings. It need scarcely be said that it is still more important to keep these principles in view in the case of large public buildings and towns.

I hope to be able to show that by good arrangements at first this difficulty may be surmounted, and a source of danger converted into a benefit; while I think that at no distant time the proprietors of the upper lands will be very careful that the owner of the lower lands does not acquire a prescriptive right to having the sewage sent down upon the latter.

The questions, "What is the best system of drainage for a building or a town?" and "How may the sewage be utilized?" are distinct, but they must be considered together.

The whole subject ought not primarily to be viewed as one of profit and loss; that is, "Will the works that must be done to utilize the sewage pay a good interest on the original outlay and maintenance?" The proper form in which to put the question is this, "What must be done to make the principal buildings or the town perfectly healthy and pleasant to live in,

thoroughly independent of their neighbours; and while this is done, how shall the streams of the country be kept pure, and by what process shall the most profit be made out of materials which must be got rid of by some means?" The preservation of health and the saving of human life must be the first consideration; the cost of drainage or of utilizing the sewage the second; while the profit to be derived from the utilization must yield in importance to the other two. I hope to prove that the least outlay will be incurred, and the greatest return obtained, from the most sanitary system.

Great difficulties (which means great expense) present themselves in altering and adapting buildings and arrangements designed upon an old and imperfect system; but for new establishments I believe the plans recommended in these pages will be found to be as cheap as any in use at present, and more satisfactory. When health or an injunction from a court of law interferes with any of the plans now generally adopted, then a remedy must be found, irrespective of the cost.

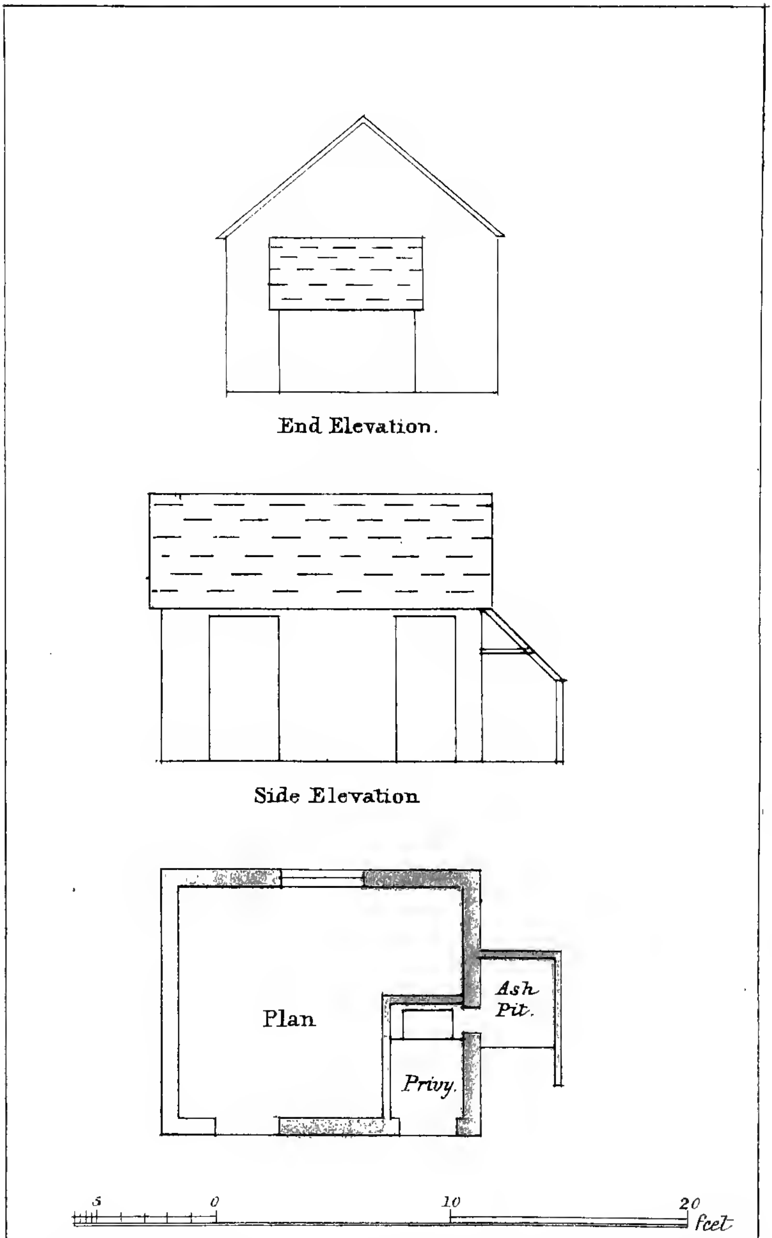
Various methods of treating sewage have been proposed, and have each their advocates. The simplest, perhaps, is that of receiving the whole in moveable large iron pans or basins, which are taken away periodically, and are emptied unmixed. This has

been much used for the habitations of the lowest class of labourers in large towns and barracks, and also in some other buildings which I have inspected; but it can never be adopted near dwellings of the better classes, for the sight and smell are so exceedingly nauseous that they could not be endured. The removal of the matter is indeed at all times a filthy operation, and the iron pans when empty smell even worse than when they are full, as there is then a greater surface exposed.

There is no doubt that this affords the least complicated means of utilizing the sewage; but the whole tendency of the people in this kingdom is towards cleanliness, and they will readily sacrifice what is apparently useful if anything so disagreeable as this is forced upon them.

This system is carried out thoroughly in China and Japan; but its advocates admit that Europeans endure a martyrdom of smells in these countries, while they forget that a vast amount of human labour is needed to convey the whole fæcal matter to the fields where it is to be used, and that manual labour in these two countries is the cheapest form of transport, while in Europe it is the dearest; also that in Britain nothing is more studied or better understood than engineering and mechanical arrangements, which involve the least outlay of either skilled or unskilled

SKETCH OF WOOD OR COAL SHED, WITH PRIVY AND ASH PIT ADJOINING.




M & N. Hanhart, lith.

labour. Neither do the towns in China and Japan yield, like those in this country, vast quantities of horse manure, which is much more easily managed, and which by its abundance in the neighbourhood of large towns in England diminishes the agricultural value of sewage.

Nor could this system of iron pans be adapted to dwelling-houses.

More may be said in favour of the Earth Closet system. It consists in placing so much dry earth or ashes in the pan, which absorbs the greater part of the ammonia, and thus renders the removal of the whole easier. For an outbuilding attached to a cottage this may, I think, answer pretty well; probably better than any other, as being cheapest.

The sketch opposite will illustrate how to do this in an inexpensive manner. The difficulty attendant on this plan lies in keeping the cottagers up to the mark in cleanliness; but this must be looked after. In the application of this system to dwelling-houses, either detached or in towns, many obstacles present themselves.

The system could not be adopted upstairs without bringing everything down through the house, which people would not tolerate. Everything used must also be washed out occasionally; and in all houses there is a great quantity of foul water (as for washing,

boiling vegetables, baths, cleaning, &c.) for which drains must be provided at any rate; and which, if not properly constructed, will become dangerous in the same manner, though not to the same extent, as if the whole sewage were passed into them. In towns, again, the vast amount of manual labour and carting required to carry out the plan, would be a serious obstacle. And, finally, the feelings of the upper and middle classes are so thoroughly against it, on the general principles of cleanliness, that it would be useless to attempt to introduce it into any respectable house.

Thus, looking at the question in all its bearings, I am forced to the conclusion that the Water Closet system will supersede all others, while I believe that I shall be able to show that, agriculturally speaking, it is the best and most profitable.

Nightsoil alone, and undiluted, if applied to land, is too hot for the crops, and, from its strength, is apt to burn them up; but it becomes the best of all dressings when diluted in a certain quantity of water. Anyone who has had much experience in dressing land with guano knows that the result of applying this essence of manure depends almost entirely upon the quantity of rain that falls after it is put upon the land; indeed, all manures are best appropriated by plants when they are embodied in a certain quantity of water.

## CHAPTER II.

### THE SANITARY CONSTRUCTION OF HOUSE-DRAINS AND CLOSETS.

THE first principle to be kept in view in constructing Waterclosets is that they and all the other parts of a house (such as housemaid's closet, scullery, kitchen, &c.) from whence foul water must be removed should as far as possible be all on one side of the house, and that their outlets should enter at the nearest point into one main drain. These parts of a house should also all communicate with the outer air, and be on outside walls for the facility of ventilation, and for the practical reason that, if any repairs or examinations are necessary to the drains, they can be reached without pulling up floors or otherwise injuring the building. If the drains must be made inside the house let them be along the passages, but take them outside by the shortest line.

The aspect chosen for closets and foul drains should be the north or east, because these are naturally the coldest, and it is advisable to keep these parts of the houses cool, so that the heat of the sun should not draw up the foul air out of the drains, which it would have a tendency to do.

The kitchen also ought to be kept on the same side of the house, so that the heat of the sun may not interfere with the kitchen fire.

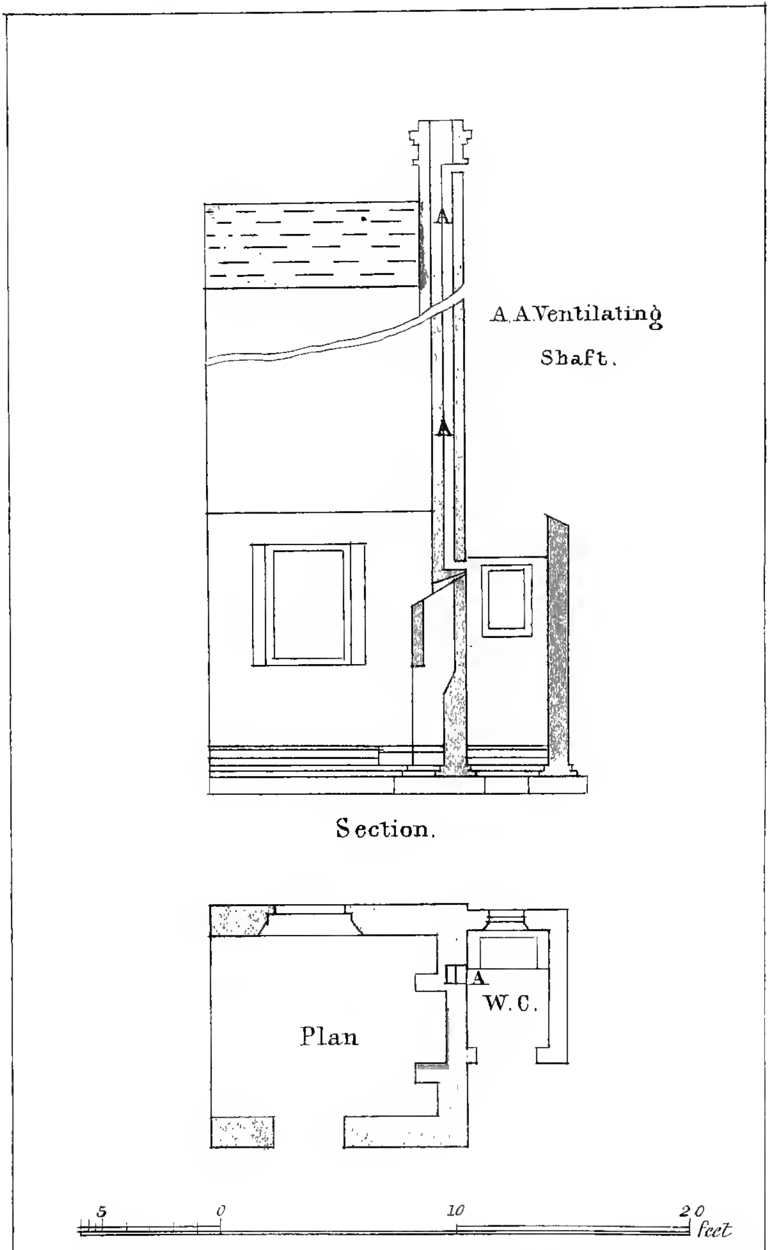
If these rules are followed the members of the family must necessarily live in the south, east, and west sides of the house, where the sun's rays, however hot, produce during the greater part of the year healthier air than what is found in rooms that do not receive the sun. It will make two months' difference in firing to a labourer in the year, besides adding immensely to his comfort and happiness, if his living-room is placed due south, as contrasted with one due north.*

To keep the supply pipes and cistern of closets from freezing during the winter, casings of felt should be placed around them.

In order that the water may come to the closet as soon as it is wanted, the cistern should be placed as near to the seat as possible; and the cistern should be used for that purpose alone, and not for domestic requirements as well, so as to prevent contamination. The trapping of the overflow of these cisterns is very often forgotten, but it is essential. The window of the closet should reach to the ceiling, and should be open as often as possible; but as this

* These recommendations cannot of course be followed in towns; but should be considered wherever there is a choice.

# METHOD OF VENTILATING WATER CLOSET.




M & N Hanhart lith

cannot always be done by night and by day, the sketch opposite gives a plan for carrying off any foul air that may be in the closet itself. In this plan it will be seen that the heat of an adjoining flue causes an upward current of air, which will exhaust the closet. In large public closets, used by a number of men, the pan or basin should always stand full of a measure of water about one foot or eighteen inches deep, and have a valve at the bottom for allowing the whole to pass off into drains.

Much trouble has arisen in towns and barracks where great quantities of hay and shavings are used by the men, and then thrown down the drains. These, as well as pieces of rags, &c., do not dissolve in water, and gradually accumulate at some point until the whole pipe is blocked up and the drains must be lifted.

The sketch opposite page 12 gives the only means I have yet been able to find out to meet this difficulty. It will be observed that a special chamber is constructed, into which all these materials are thrown by the men, and from which they can be removed without any nuisance arising.

These large closets must be ventilated on the same principles, and charcoal air-filters used if necessary, in a manner to be afterwards described.

I need say little on the subject of old brick drains or dry stone drains, as they are entirely obsolete; and if any remain about a house, the sooner they are pulled up the better.

Houses built upon gravel are generally supposed to be the healthiest; and so they are if their drainage is good. If however that is leaky or imperfect, the sand or gravel readily absorbs the impurities, and the house becomes worse than it would be if built upon clay, which is less absorbent and soon becomes puddled round the pipe.

For sewage drains nothing equals the elliptical or circular-shaped glazed pipes. At every twenty yards, one pipe should be laid in the line of the drain, from which the upper half can be removed for inspection or for inserting a flexible rod to remove any obstruction. The best amount of fall to be given to a sewage drain lies between one inch in ten feet and one inch in six feet. If the fall is greater than this the water flows away too rapidly and leaves the solid parts behind; if less than this there is a risk that the solid matter may accumulate in the pipes.

Outside the kitchen and scullery there should be a cesspool, in which the fat contained in the waste-water may be congealed before the liquid enters the drains.

There should be no sharp turns or angles, but easy sweeps, if these are necessary.

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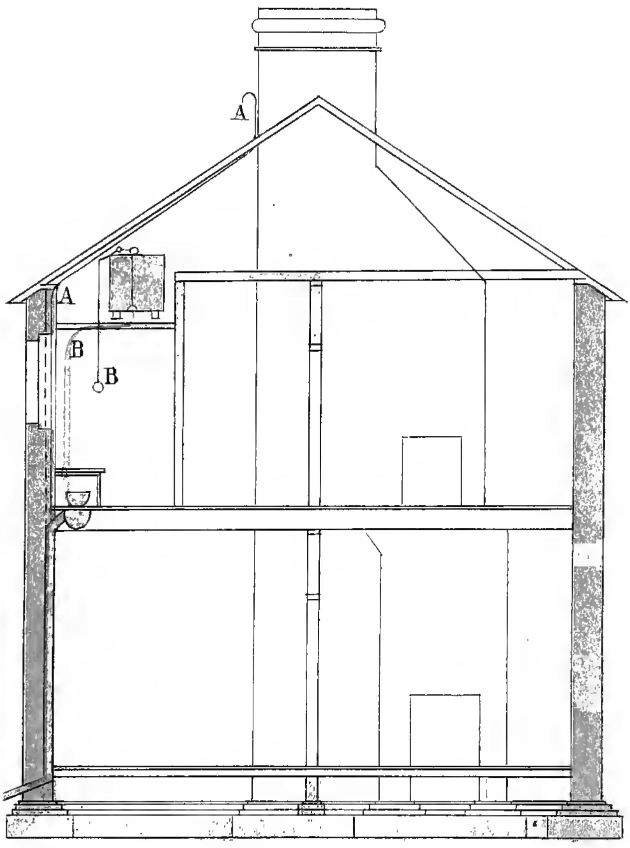
Any foul air existing in drains (and under any system some must be generated) should have a free and safe outlet provided for it, so that it should not, as it is produced, constantly press upon every trap placed to prevent its exit where it ought not to come. The moment that the handle of a closet is pulled the trap acts imperfectly, and the foul air gurgles back into the house. Where many people in large buildings use the same closet, the whole foul air in the drains is thus frequently discharged into the buildings, generally into the bedroom passages.

The gas which arises in foul drains is of a singularly light character, and has a tendency to ascend or draw towards any heated part of a house. Hence it often arises that houses in towns situated on the highest ground are more unhealthy than those in the valleys; the foul air rises to them through the drains.

As during the greater part of the year the internal temperature of an inhabited dwelling, and especially of some parts of it, is much higher than the surrounding atmosphere, it is obvious that the gas naturally ascends to the living-rooms, especially if during the winter and autumn they are warm and comfortable. It becomes still more important to keep this point in view since the great introduction of hot air into dwelling-houses, raising their temperature constantly

to probably sixty degrees, while the outside atmosphere may be at freezing-point. These closets are also generally in the bedroom floor, and it is more unhealthy to sleep in foul air than to be in it during the daytime. I have known this dangerous gas pass through floors and through chinks of two-feet walls, and it will find out the smallest opening in any pipe that will give it a chance of getting to the heat or the open air. I need not enlarge on its injurious character. Fevers are engendered and fostered by it; children of weakly constitution are sure to suffer and often die from it; ophthalmia, dysentery, erysipelas, hospital gangrene, and indeed a multitude of diseases, follow in its wake. It becomes, therefore, of the first importance to provide for it an outlet or, in fact, a safety-valve. Probably no way has been found as yet better than that shown on the opposite page, where it will be seen that a continuation of the soil-pipe is carried on up to the highest chimney, and the gas there allowed to escape and disperse in the open air out of the reach of all windows. If a very perfect arrangement is desired, so that foul air cannot possibly escape into the house, either through the soil-pipe or ventilating pipe, it may be done by plugging up one end and testing them by hydraulic pressure. Any small hole in these pipes is by this means certain of being discovered. Another safe

PLAN SHEWING METHOD OF FLUSHING AND VENTILATING SOIL PIPE.




A.A. Ventilating pipe.
B.B. Flushing apparatus and pipe.

M & N Hanhart, lith.

plan of ventilating drains is to bring a communication from a foul drain into the chimney of some shaft, such as that attached to an engine-furnace, where a fire is constantly going, which will draw out the foul air and burn it at the same time. But unless the chimney is in daily use this plan would not be safe, as the flue must always be heated. If the chimney becomes cold, and the room below warmer than the external air, there would be risk of a down-draught which would bring the smell into the house.

As the water used for the ordinary purposes of waterclosets is not sufficient thoroughly to sweep out everything that is in the pipes, the flushing of the drains is essential. A small stream of water running constantly does not produce the same effect as a sudden rush from a larger pipe; and this rush should also take place without the force of the stream being broken up more than can be helped. The sketch opposite page 14 will show a good method of sending down such a sudden current. By this means the *blow* of the water comes at the points where the stoppage of any sediment is most likely to take place.

Large public drains must be ventilated and flushed on the same principles. House-drains should be flushed at least twice a week, for this reason—that for

the first two days after it enters a drain the gas arising from sewage, however disagreeable, is not dangerous; it is only after the third day, when putrefaction begins, that the gas assumes a different character and becomes noxious.

As to the size of sewage pipes, it is seldom advisable to use a pipe smaller than six inches in diameter for a main drain in any house where above eight people reside; and this size may be gradually increased until one of a foot diameter is reached, which will take the sewage of 500 to 1,000 people, especially if the rain-water is kept out of the drains. This should be done for other reasons, which I now proceed to mention.

# CHAPTER III.

## THE PREPARATION OF SEWAGE FOR IRRIGATION.

RAINWATER either from the roofs or from the surface of the ground ought never to be allowed to pass into the foul drains, unless it is under perfect control. If it is not necessary to utilize the water from the roofs by storing it in a tank, the whole should be conducted to the nearest point at which it can pass away by the natural watercourses of the country.

Rainwater stack or upright pipes are generally made to discharge into the foul drains, with the precaution of a trap at the bottom of the pipe. But during dry weather the water in the traps evaporates or escapes otherwise, and the gas comes back into the house. The distance foul air will travel, and the extraordinary manner in which it will find out any point at which a trap ceases to act, may well excite astonishment; for, in fact, it will frequently pass through water with a bubbling action.

In other cases the rainwater pipe is passed into the foul drain without a trap, and the pipe is then intended to act also as a ventilating pipe. This is the best

and, I believe, the only argument in favour of thus disposing of rainwater. In most cases the rainwater pipes are not carefully prepared for this purpose; but when this is done, it is obvious that they must be carefully jointed, at considerable expense, so as to prevent the gas escaping as it passes upwards; and the point of delivery of this gas must, when the rain-water pipes act as ventilators, almost always be at the *eaves*, instead of at the chimney-head, as shown in my sketch at page 14, as being a preferable system.

It frequently happens, when the delivery is at the eaves, that during heavy dull weather in autumn, or with a strong wind in particular quarters, when the gust is diverted and eddying among the irregularities of the roof, the escaping gas is driven down from the point, where the rain-pipe ends, into the windows of the bedrooms, and that the rooms cannot then be aired. The case is worse where there are attic windows in the roof. It has also been urged in favour of using rain-pipes as ventilators, that they present so many outlets to the gas as to prevent its concentration. What the amount of ventilating shafts or tubing should be for each house or building it would be impossible generally to specify; but it appears to me that the rain-water pipes act only as second-class or supplementary ventilators, and that it would be safer to confine

them to their legitimate purpose, and provide a sufficient number of pipes specially constructed for the ventilation, and carried high enough to be out of all danger.

Many other reasons will appear in subsequent parts of this book, which will show how desirable it is that the rainwater should be kept separate, and therefore the use of the stack-pipes as ventilators must be made to accommodate itself to the general scheme. I believe also, if the plans I am advocating are studied and carried out *from the beginning*, in the case of any town or large building (and thus only can we compare the two systems), that this separation of the rainwater from the sewage is the most economical; because, at a short distance from a house, rainwater may be discharged into an open ditch or watercourse of any kind, whereas if it is mixed with the sewage, the whole must be conducted to a greater distance from the house in larger pipes than would be required for the sewage alone, and consequently greater expense must be incurred.

If rainwater is needed for domestic purposes (and for such uses it is generally the best), it is almost always necessary to filter it. The impurities in such water arise from the droppings of birds upon the roofs, decayed leaves, and the falling of soot into the spouts.

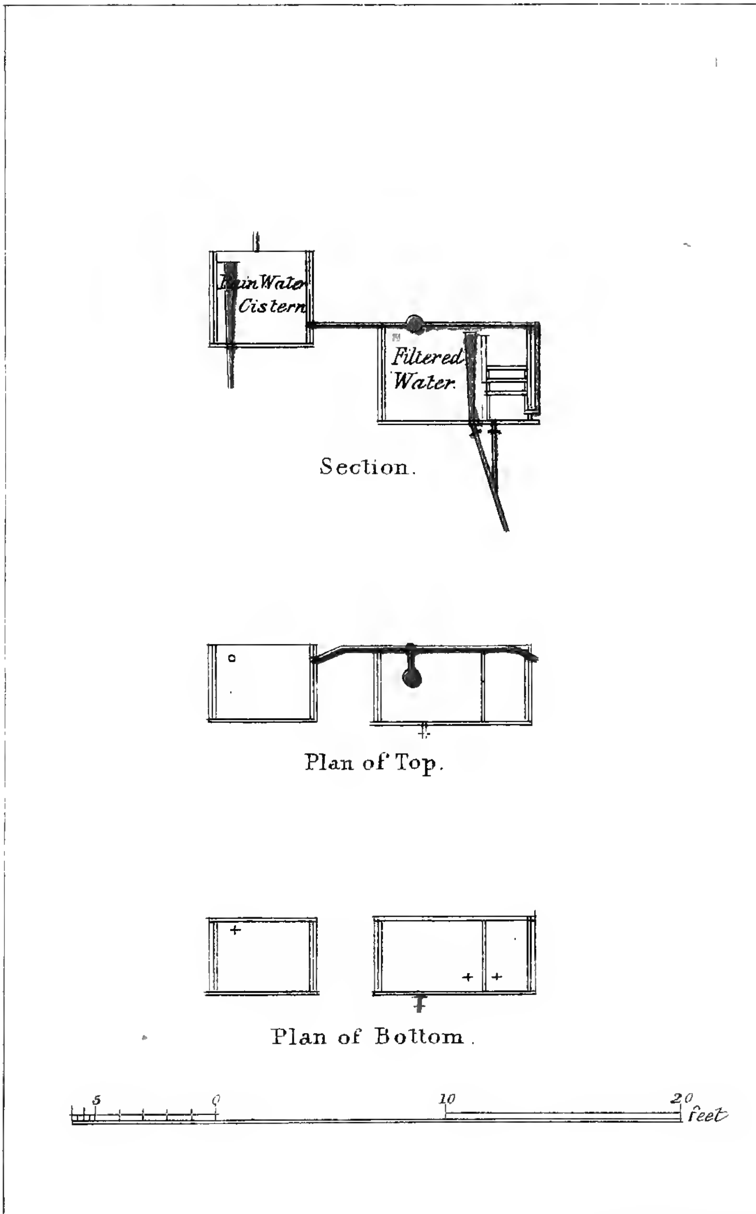
Probably no form of filter for rainwater is better than the ascending and reversing filter shown on the opposite page, by which the beds can be cleansed without taking them out.

The sewage of any building, unmixed with rain or surface-water, having been conducted away from the house in the manner I have described, the next step is to deal with it: and here we must note some of its peculiarities.

For the first three days after sewage is deposited in water, the solid parts are lighter than water, and float on the surface apparently in their original state. After that time they gradually dissolve, a considerable part of their ingredients becoming embodied in the water, and the residue falling to the bottom, where it remains about a fortnight; after which period a portion of what has sunk rises again, having formed some new combination, and floats in the shape of a thick pasty substance. This double action has presented no ordinary difficulty, and made all deposit tanks quite useless. It is essential to deal both with the solid and liquid parts during that fortnight.

Little need be said about Cesspools, as they are universally acknowledged to be highly dangerous, and should on sanitary grounds be done away with at once. If they are watertight and retain all the

# PLAN FOR FILTERING RAIN WATER




M & N Hanhart lith

ingredients, putrefaction commences, and an overflow must also be provided. If they are porous and allow the matter in them to soak into the earth, then the wells in the neighbourhood run the risk of being poisoned; while any attempt to utilize sewage that is contained in cesspools, economically, through pipes, will be imperfect. If an attempt be made without filtration to apply the solid and liquid parts to land for irrigation during the first two or three days after they are deposited, the solid parts, being on the top, lie on the surface; are offensive to the sight; and dangerous, because putrefaction goes on in the open air.

If, further, the sewage from cesspools, without filtration, is conducted through pipes for irrigation, it will be found very difficult, if not impossible, to force it along. The pipes get clogged, and something will give way if pressure is applied. If pumping has to be employed the difficulties increase. Simple lifting by a centrifugal pump may be done; but if force-pumps are applied, then paper, hay, straw, linen, and many other similar substances, which are found in all drains, get into the valves and choke them, and they burst in consequence. In fact, the suction-pipe itself soon ceases to act.

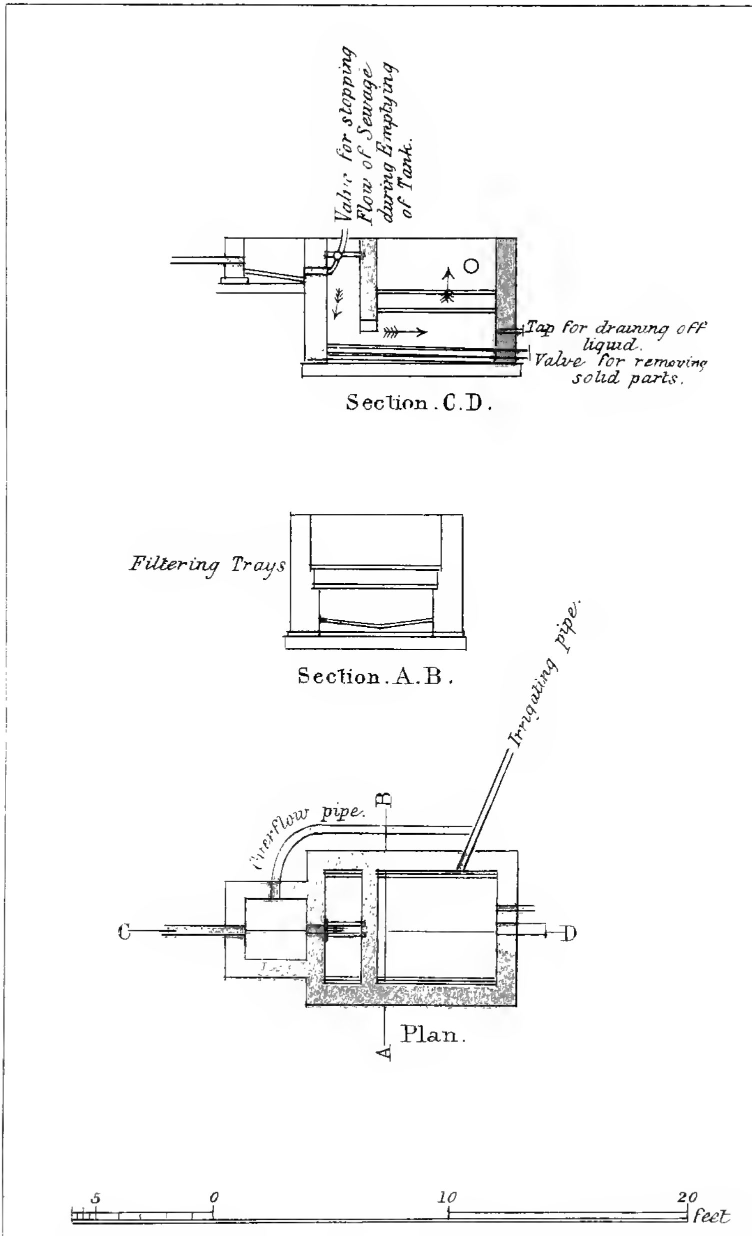
It is not prudent to attempt to reduce the sewage

to a pulpy mass by agitators, as this involves machinery and risk of nuisance, and some of the ingredients I have mentioned cannot be broken up.

The solid parts of sewage in dry weather, if allowed to discharge into a river, will float along and be little changed in their character after being conveyed three miles in a running stream which has a smooth bottom, and travelling at the rate of two or three miles an hour. This is important in a legal aspect, as bearing on the subject of nuisances.

The advisable method, therefore, is to pass the sewage through filters or straining tanks acting upon the upward or ascending system; so that when, after the third day, the solid parts fall to the bottom, they may get in below something which will prevent them from rising the second time. No filtration acting by a downward or side process will continue to act, because the very act of filtering clogs the pores through which the liquid is to pass. In the upward process, however, we have two forces acting in opposite directions,—namely, the solid matter descending under the power of gravitation, and by the force of the current; the liquid ascending through the beds to the level of the incoming pipe. The principle is shown in the drawing opposite. The construction of these filters requires much consideration in detail.

PLAN SHEWING PRINCIPLE ON WHICH SEWAGE FILTER MAY BE CONSTRUCTED.




M & N Hanhart, lith

It might only mislead were I to go minutely into this minor subdivision of the subject. The rapidity of the fall of the incoming drain; the nature of the ground in which a filter is to be built; the number of people for which it is to be adapted; the distance from the house at which it may be placed; the material available; the size of the overflows; the thickness of the intercepting beds; and many other smaller but important details enter into the question.

The one I have shown would serve for a family of ten or fifteen people, and require cleaning out once a month or six weeks.

Every engineer adhering to the principle of upward filtration must work out the remainder for himself. It is also essential that the filter should be watertight.

It might lead to failure, and would be of little benefit, were I to give particular drawings or estimates of these without considering the speciality of each place. For large buildings two of these must be built side by side; the one in operation; the other being emptied. To the Prince Consort belongs the entire merit of first perceiving the principle of upward filtration, and designing such a tank as would continue to act. I had before he pointed it out made many attempts at filtering sewage-matter, but

all had failed. In the spring of 1858 the Prince Consort sketched in my note-book the only plan upon which he was satisfied these tanks would remain efficient; and much subsequent experience has proved that he was right, and had opened the way for a great public benefit, for nothing satisfactory can be done without them. The first was built at Osborne about eight or ten years ago. Since then they have been much improved, and five or six are now in regular operation, not one of which have failed.

The general expense of one for a family, such as I have shown, would be from £12 to £15, according to the locality. I would here also remark that unless the rain and surface water are kept apart from the sewage, filtration is in most cases impracticable. For large towns it is absolutely so.

There are several great advantages gained by filtration. The first is, that whereas unfiltered sewage passing through pipes should have, if possible, a descent of one inch in ten feet, the liquid when filtered will flow with a fall of one inch in twenty yards. Further, unfiltered sewage will not go down and up again in an iron pipe, and so will not pass over a valley; but filtered liquid will. Filtered liquid can be pumped and forced, so that the whole can be more easily guided away in the direction wished for purposes of irrigation,

and gravitation may be more frequently made to do the work. Also after the sewage is filtered, a pipe, probably little more than half the size of the incoming pipe, will convey away the overflow of the tank.

This direction for the overflow, and the land selected for irrigation, should, whenever it is practicable, be on the north or east of the main building or town; because the south-west wind blows for two-thirds of the year in this country, and more especially in summer and autumn. It is well that two pieces on opposite or different sides should be available for irrigation.

Although filtration and irrigation may frequently be adopted on the other sides at safe distances, it would be preferable, when there is a choice, to select one of the two I have mentioned.

Another advantage of filtration is, that the solid or deposited parts can all be removed by laying the filter dry, for which means are provided; and as house ashes or peat ashes make as good a filtering bed as any, and are always attainable without great expense, a rich compost is formed, which can be carted away.

It is surprising how little of this solid matter remains underneath the filtering beds. The stream of water constantly passing through it seems to have great powers of dissolving and carrying off what is deposited.

Gas-lime is almost always to be had conveniently, and this can be thrown over the mixture in small quantities, so that in cleaning out these filters there is nothing particularly offensive. The matter may be pushed through the valve at the bottom into buckets or a cart, without any handling by men. Chemically speaking, better substances might perhaps be found than ashes and gas-lime for mixing with the solid parts of sewage, so as to fix the ammonia, but gas-lime and ashes do very well; and as the other articles would have to be bought, and would probably thus be neglected, while these are generally on the spot, everyone is sure to give them preference, and quite rightly.

The uppermost and last beds of the filter in all cases should be gravel, to prevent the loose ashes being washed away by the uplifting power of the water.

As filtration by an upward process is, therefore, the only safe one, and is essential, it is obvious that the weight of the resisting beds of filtering material must be sufficient to prevent their being entirely uplifted by the ascending water.

Trays of small wood-charcoal placed over the beds of the filter will be found quite efficacious in neutralizing any smell, and this charcoal may be used again

and again without losing its power, by drying it over a fire. The charcoal must be kept dry, or else it will cease to act.

When the solid matter is treated thus, and the liquid passed on for irrigation in the manner subsequently described, all other disinfectants and deodorizers may generally be dispensed with.

Although it is not absolutely necessary, the filter, where this can be done, should also be ventilated by an open pipe passing up into the air.

In forming these filtering beds, and planning the irrigation afterwards, if that is done, another of the advantages of not allowing the rainwater to enter the same pipe or drain becomes apparent.

It will be found that, in ordinary families of the middle and upper classes in the country, for all household purposes whatever, the usual quantity of water per day consumed ranges from eighteen to twenty-five gallons to each person. In large asylums and public buildings it is sometimes double, and in large towns rather less. This quantity is easily ascertained, and a fixed amount within certain limits is thus arrived at, if the rainwater is kept apart.

But if the latter is allowed to come into the same drain, a larger pipe must be used than is necessary for the sewage, so as to meet the contingencies of floods,

which larger pipe again, in dry weather, gives too much room to the sewage, and is more liable to get clogged than a smaller one, where the flushing stream will be more concentrated. But, principally, in all mechanical, chemical, and engineering operations, like the construction of these filters and subsequent irrigation, fixed quantities, such as are produced by the sewage and flushing water when alone, are more easily and more economically dealt with than uncertain quantities, such as is the flow through the pipes and over the surface of the land, when great gluts of rain must be dealt with as well as the sewage.

Further, the greatest flow of sewage and household water always comes down during the early part of the day, while a flood of rain may come during the night and disturb all arrangements, when there is no one to remedy any mishap. I shall speak of this subject again, when I come to treat of the Drainage of Towns.

Twenty-five gallons per head of the population of any town is the extreme limit of dilution that can be recommended for agricultural purposes. This, it must be recollected, must be provided for during the whole year. In summer, when plants are growing and vegetation active, it is speedily absorbed. For sanitary reasons, in hot and dry weather when there is no rain, frequent flushing is advisable, and the land agricul-

turally is then in its best condition for receiving it. In winter, again, we have the greatest quantity of rainfall and the least evaporation, as also the greatest disturbance of the surface of the fields from frost and snow, and plants are then in their dormant condition. The earth is then receiving as much rainfall as it can naturally absorb. Thus the exclusion of the rainfall not only does no injury during the summer, but is essential in the winter, in order that the liquid coming down may then be reduced to the minimum. If, therefore, arrangements have to be made to utilize the sewage of 500 people, using for flushing and all purposes twenty-five gallons a day, we have fixed data on which to proceed; not only daily, but even at particular hours; so that we obtain uniformity, which results in economy.

On sanitary, engineering, and architectural considerations, the quantity of water sent down the drains daily should not be under ten gallons each person. The most advisable quantity lies between that and twenty-five gallons per head, according to the fall of the drains and the character of the soil on which the irrigation is to take place.

# CHAPTER IV.

## METHODS OF IRRIGATION.

The sewage-filter should be cleaned out every month or six weeks. The material obtained by deposition under the filter beds will be in a semi-fluid state, but will become solid in a few days. Agriculturally speaking, the more frequently the filter is cleaned out the more valuable will the solid matter be.

This deposit should be mixed with the ashes of the filtering beds, by that time also saturated with ammonia, and a valuable manure is obtained, which can be carted away at leisure, without being offensive either to sight or smell in any great degree.

No satisfactory data exist in this country to enable us to form an idea of the annual amount or value of this solid matter per head of the population, after being some time in water and forced under a filter; but I believe it to be much less than is generally supposed, for reasons that will subsequently appear.

The liquid, after it rises through the beds during

the first ten days or so, will be in a comparatively transparent state. After a fortnight the liquid gradually becomes darker and stronger until the filter is emptied.

I would here remark also another argument in favour of the water-closet as against the earth-closet system of dealing with the sewage generally. All accounts that have been given us of the Chinese and Japanese methods of dressing the land with excreta invariably say that, knowing it has most effect agriculturally when mixed with water, they largely dilute it before applying it to their fields. Abundant evidence on this subject may be obtained from the many books written within the last two or three years on the customs of these two countries, and from the evidence given before the Committee of the House of Commons.

I will only quote what is stated by James White, Esq., M.P., in May 1862, and published in the Second Report of Dr. Brady's Committee. He says, speaking from his own knowledge: "The custom in "China is daily to take from the houses all excre- "mentitious with any other animal and vegetable "refuse, for manurial purposes. When this sewage "is taken into the country it is deposited in a "tank or shallow well, which is ordinarily found

"at the corner of almost every field. The way "in which they put this sewage upon the land "is, that they take a small quantity, a scoopful, "and put it into a bucket of water, and in this very "diluted state the cultivator throws it over his crop, "or applies it to the root of each plant. I should say "that the proportion when the excreta is diluted is "about 12 to 1." Nurserymen in this country, however, know this principle equally well.

Mr. White also describes a system followed in China of collecting the solid matter and drying it in the sun, so that it may be sold in the form of *poudrette*, and in that state it is largely exported to the sugar-growing countries. This is also done to some extent in Paris.

I fear that the feelings of the people of this country would not soon, if ever, become reconciled to this process being carried on daily in our streets. Besides, the relative cost of human labour in China as compared with the results of engineering arrangements here, as I have previously pointed out, would be much against it in England.

I may illustrate this principle, which is an important one, by pointing out that although the wages of common labourers, such as are accustomed to transport packages of tea from the hills in China, are about 2*d.* a day, while here we pay 2*s.* 6*d.* for the same amount

of work, yet our railways will carry a ton of merchandise 100 miles at less cost than it could be done in China. The amount of dilution that exists in this country is perhaps nearly twice as great as that which is adopted in China; but, considering our habits of cleanliness, this cannot easily be surmounted. I believe however that in towns, as I shall afterwards show, the amount of dilution may be much reduced, with many advantages. If this could be done in houses in the country also, it would be advisable. My experience is that sewage diluted with twenty-five gallons a day per head of the population is, after filtration (which is principally a *mechanical* process), so valuable as to be well worthy of being applied to irrigation. In this case the agricultural aspect of the subject must accommodate itself to the sanitary.

The liquid, after passing through the filter of ashes and gravel, still retains a vast amount of fertilizing material in the shape of ammonia and other salts, and its effects in summer upon vegetation are remarkable.

Where the whole sewage-water after filtration will flow by gravitation over a certain area adapted for it, which can be obtained at ordinary agricultural value, there can be no question as to the advisability of the process, and to the fact of the returns paying ample interest on the outlay.

If steam must be used to raise the liquid, it is always better to force the supply up into a small reservoir at the highest point, and then to irrigate by downward pipes, than to irrigate from pipes under pressure and from an ascending current.

The latter must be done, however, to some extent when the land to be irrigated is quite level. In the case of public buildings, I should hesitate to say that it would be a profitable investment, except under special circumstances, to erect a steam-engine and all machinery necessary for the purposes of irrigation, unless the engine can be put to some other good use at the same time, so as to lessen the cost of supervision and maintenance. I mean by this that if, for instance, a six-horse-power engine is required in any establishment for pumping pure water from a well, or for laundry or other purposes, and by increasing this engine to ten-horse-power the pumping of the sewage-liquid can be done at the same time—under these circumstances, and under favourable conditions of soil and situation, I think that such a plan may be recommended. (*a*)

The sewage-liquid, even after filtration—which, on the principles already suggested, is only, or principally,

(*a*) For large towns, of course, steam must be used for pumping, when that is necessary.

a mechanical process of separation—will still have a strong smell. A mixture of lime-water and carbolic acid will be found effectual for a considerable time in fixing or overpowering this effluvia ; but my experience is that the water thus impregnated with carbolic acid is less beneficial to vegetation, and therefore does not fulfil all the requirements of the case if the liquid is to be utilized.

Besides, I have no doubt but that any owner of property through which the sewage, even when so impregnated, passed immediately afterwards could successfully bring an action to prevent its coming to him unless he chose to receive it. He is entitled to receive the water through his property pure and uncontaminated, as it would be naturally.

It would then become compulsory to utilize it, when a steam-engine might have to be built. If steam must be employed, then, as this engine cannot be kept going night and day, a receiving tank outside the filter must be built large enough to hold the whole of what would come down during the night ; and this could easily be ascertained and regulated, if the rain-water were excluded.

If water-power for pumping can be obtained cheaply, there are, of course, greater advantages than in the case of steam.

Light free sandy loam is the best description of land to be selected for irrigation. It does not matter how poor it is naturally: pure sand itself, when deep-trenched, will soon become fertile under the powers of the water. The soil ought almost always to be thoroughly underdrained at five feet deep, and with pipes not farther apart than ten yards.

If the soil is stiffer the drains must be closer. The best slope for irrigation is about one foot in thirty of fall. The land also must be thoroughly trenched, or subsoiled two feet deep at least. The trenching is best, and the top-soil should be kept at the top, and not put at the bottom, if grass is the object in view: for kitchen-gardens top and bottom soil should be mixed. If clay-land only can be obtained, then burning the clay so as to make it porous would be an advisable step. The land must also be clean and free from weeds. It is more advisable to take ploughed land and prepare it specially than to irrigate old pasture.

It is essential that the water used for irrigation should always be kept moving either along the surface or downwards through the soil: there must be no standing-still of the current, as putrefaction then begins, and injury would be done to the roots of plants. The quantity of this water which sandy soil will absorb with advantage is surprising.

The whole of the water used by 100 people, on the allowance of twenty-five gallons a day for each person, may be utilized annually on an acre or an acre and a half, if the crop to which it is to be applied is a mixed one of vegetables and grass.

If grass alone is to be irrigated, a smaller area will be sufficient. On the other hand, if the soil is stiff clay, I should allow a larger acreage, so as to give time for the liquid to be absorbed. In the case of a large town I should recommend a larger quantity on a smaller area.

Irrigation with sewage-water upon very level stiff clay ground must be undertaken with great caution at any time, as success is very doubtful; and I consider it scarcely advisable. The engineering details are necessarily more elaborate, and great expense must be incurred to prepare the ground for it, and to relieve it of the water afterwards by under drainage.

It appears to me that the utilization of sewage by growing food for man and beast, as being the most satisfactory issue, should always be the first object in view; but, from what I have stated, there may arise cases where the land is so unsuitable, and the engineering difficulties so great, that any attempt to carry out the plan may be too costly: and the question then is, what is to be done?

Filtration can be accomplished under any circumstances; and the only other marketable product which we can obtain with our present knowledge from sewage-water is sal-ammoniac. This is extracted in France by a species of distillation, whether profitably or not I cannot say; but the dilution of sewage-water there is very much less than in this country.

The liquid from which sal-ammoniac is extracted there is the overflowings of cesspools, with scarcely any water added; while in England we cannot hope to have a less dilution than fifteen gallons per head. We require further researches from our chemists in this direction.

It might also be cheaper to destroy the ammonia and other salts entirely, and then allow the liquid to pass off into the streams. This can be done, I have reason to believe, by passing the whole through filters of magnetic carbide of iron; and the expense would not be great, as the filtering material may be dried in a furnace and used again. On this point I cannot speak with confidence; we require experiments on a much larger scale than any that have yet been made. The process should never be resorted to but in extreme cases, as it is a destructive one, and nothing saleable is produced.

With regard to the crops to be grown under irrigation, grass is decidedly the best.

However good any previous pasture may be on land proposed to be irrigated, it is better to break it up, trench or deep-plough the land, and sow it down with Italian ryegrass and clover. If a little chalk or lime can be added it is in most cases a good ingredient.* This ryegrass and clover should be sown in autumn or spring, and the irrigation may be turned on, except in winter, as soon as the plant has grown to be two inches long. As Italian ryegrass, however, is a biennial plant, the ground must be dug over at the end of the second year and fresh seed sown, or a crop of vegetables taken, which will alternate well with it.

But if the process is to be perfect, irrigation must go on every day, summer and winter, without regard to weather; and a difficulty arises in knowing what to do in hard frost, as the liquid should

* Since this work was in the press, a letter has appeared from Baron Liebig to Lord Robert Montagu, urging the application of phosphates to land irrigated with sewage. Practically, as stated above, I had discovered the same thing. The case of the Edinburgh meadows, which have gone on for 50 years without lime, has been quoted to the contrary. But the streets of Edinburgh are all macadamised with blue trap or whinstone rock, which is so full of lime that, simply by the action of rain and traffic upon them, they bind into a hard concrete. The washings from these streets all pass into the drains along with the sewage, and supply the lime. The street washings of themselves would be an excellent dressing for grass. The case is different where streets are paved with granite.

not be allowed to freeze on the ground. To meet this, in the second year, before the Italian ryegrass is dug over, allow the last crop—say from August to November—to grow and become very long, probably eighteen inches. This will keep out a pretty severe frost, and the irrigation may proceed among the roots of the grass. The injury done to the grass would not signify, as it is to be dug up for vegetables.

Where the earliest grass, which is the most valuable, is wanted, let the irrigation be laid on under the shelter of a wood that protects it from the east wind.

The grass should be given green to milch-cows, along with some other drier food, and sparingly to other animals, as it is apt to produce scouring, and will not, if grown too luxuriantly, lay on fat. This arises from the quantity of water in its composition, and its deficiency in sugar and starch, which only time and the sun can mature.

The grass, if forced to grow rapidly, will not, for the same reasons, make good hay. Under ordinary circumstances, and with a sale for such grass, it may be cut from four to six times, at least, during the year, and is worth about 10*l*. an acre annually to rent, if the supply of liquid I have mentioned is available for irrigation. I am aware that much higher rents have been madeand are realised—at Edinburgh, for instanee ; but

that is quite an exceptional case; the process is there carried on under the most favourable condition, and the ground receives an enormous flood of water, while the sewage is sent into the sea when it is not wanted. In the interior of the country we must provide for the liquid all the year, and, generally speaking, all irrigation in the winter does nearly as much harm as good. In Devonshire we may say there is no winter, and the great benefit which ordinary irrigation there produces, is by depositing upon the land a thin film of alluvial matter, held in suspension in the water, and brought down by the first heavy rains in November.

Agriculturally considered, it is better in summer to put a large quantity over a small area than a small quantity over a large area; in a sanitary view, the reverse is the case. What I have recommended is, in my experience, the advisable medium.

This part of the subject requires experiments on a larger scale, and of a more methodic kind than any that have yet been made. Correct data for determining the value of the grass do not exist. My opinion is taken from observations of what has been done in establishments containing from 300 to 600 people.

As this subject is still in its infancy, and requires further developement, I should not advise anyone to grant a long lease to a tenant upon the terms I have mentioned.

Kitchen-vegetables come next to grass in order of merit; but of course these cannot be forced so rapidly, nor during the whole period of their growth, while also they must have time and the sun's rays to ripen them before they can be used. If they are, therefore, the crop that is to be grown, about £6 to £8 an acre would, I believe, be a fair rent to charge; but this must depend upon the market for selling the product. It is obvious, however, that large sewage-works can only be undertaken near a large town or public building, where grass and vegetables would be much in request.

Under sewage irrigation, celery, cabbages, onions, greens of all sorts, rhubarb, strawberries, scarlet runners, peas, and potatoes are the crops that do best; and it is essential that the liquid be applied when the plants are young and growing, and not when they are ripening. Neither is it of much benefit to apply the sewage-liquid to bare land or fallow. If applied to cereal crops it must be done very cautiously in their early stages, to prevent the grain from being lodged and damaged.

There are *three* methods of irrigation, which I shall now proceed to discuss.

The first is the iron-pipe system, laid all over the ground with small jets and hose attached. This is the most expensive and the least satisfactory. There is a great amount of pressure on all the different valves,

which are constantly getting out of repair; while if, to avoid friction, large pipes are used the expense is heavy. The long gutta-percha piping is costly, and liable to much tear-and-wear, and it damages kitchen vegetables while being pulled about for irrigation.

The delivery of the water is all at one point, and in a stream or glut; it is thrown high into the air, and falls like a shower upon the leaves of the plant, which are afterwards to be eaten. Some one also must always attend to it and keep continually shifting the hose. A modification, however, of this pipe system must be adopted where the ground to be operated upon is level, or nearly so; but for all general purposes, either for sewage irrigation, or for farm management, it is not advisable.

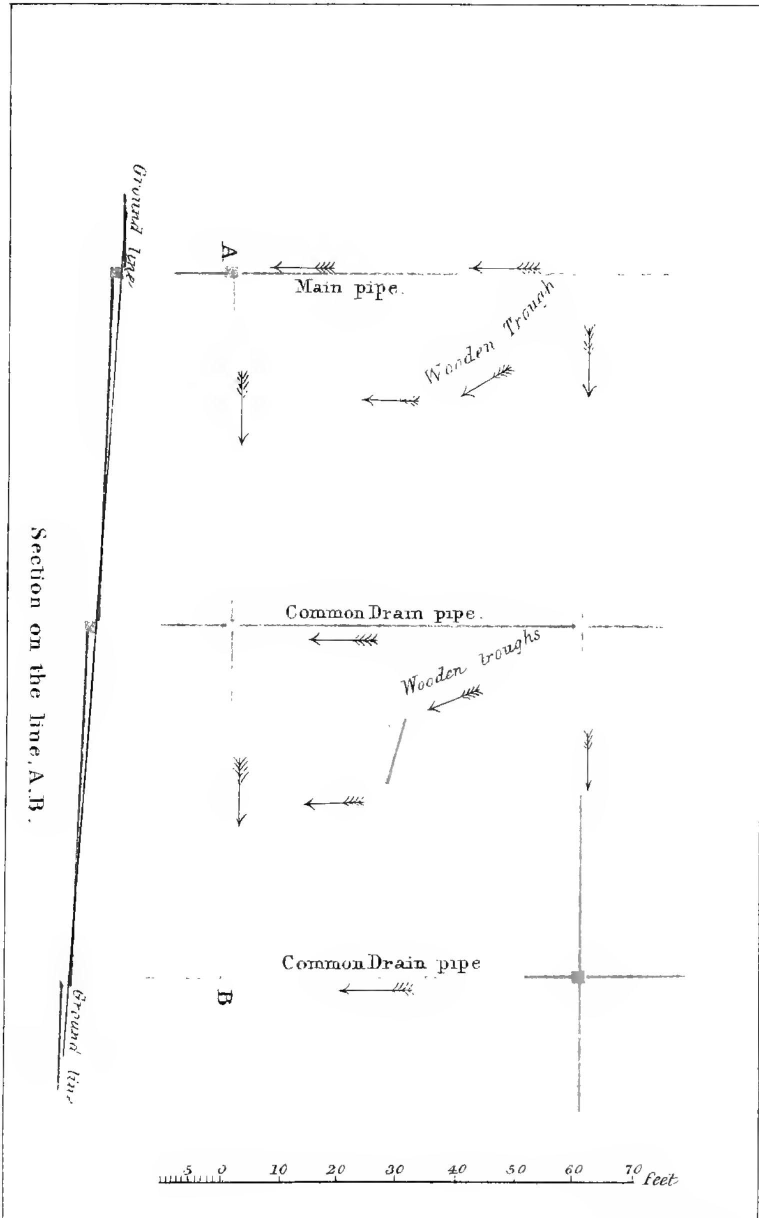
The second is the water-meadow or Devonshire system, in which the liquid is conducted by gravitation in open channels along the ridges prepared for it, and allowed to trickle down into the furrows, whence it is conducted again to other lower-lying ridges, and so on until the strength of the liquid is supposed to be exhausted. When a very large tract of land is to be treated, such as would be required for a town, some application of this method may probably be recommended. It is not, however, well adapted for kitchen-vegetables, and should not be

followed near inhabited dwellings of any size. As the liquid is exposed to the air a long time before it reaches the land its strength must necessarily be diminished. I do not consider it the most economical process, as great expense must be incurred in laying out the land at first on such levels as will distribute the water equally over the surface, while there is considerable labour in attending to the stops and sluices necessary to make the system work.

The third arrangement (which I believe to be the best) is, either by means of gravitation or by steam-power, to conduct the liquid to be used to the highest point of the land which is to be operated upon; to lay down from that point common drainpipes, almost upon the surface, in the manner shown in the plan and section opposite; to conduct the water to the point desired by merely putting a wooden plug in the holes of the small brick tanks where the water is to be diverted. At these small tanks, which are merely a few rough bricks put together, the water is made to flow into small V-shaped wooden spouts or troughs which are placed along the ground, and being laid on their side, or having a few stones or holes in them, will leak all the way along.

The drainpipes also, being laid dry, will leak at every joint, and so of themselves distribute the water.

SKETCH SHEWNG METHOD OF IRRIGATION




M & N Hanhart. lith

The advantages of this system are that, after draining and trenching, no great expense is incurred in levelling the ground, as the troughs and drains can be made to adapt themselves to minor inequalities on the surface ; the liquid never comes to the open air and so loses none of its strength, and gives off little effluvia until it reaches the spot where it is to be applied, when it is immediately absorbed. It is thus also brought directly to the roots of the plants, and not showered over them ; it can be laid among vegetables without injuring them, and it is the cheapest to construct originally and to replace from time to time. It is also the easiest to manage, and the liquid is distributed with regularity.

A common labourer would not be occupied more than half an hour every day in making all the arrangements for irrigation necessary for a building having from 500 to 1,000 inhabitants. If properly planned at first, about £3 to £5 an acre would, under favourable circumstances, be a sufficient sum to complete these last-mentioned arrangements ; but this must be considered specially for each place. These common dry draining-pipes should be used in all cases where there is plenty of water ; but where the supply is only from families of ten to twenty people, socketed and cemented pipes must be used for the main feeder, to prevent the whole leaking away

without getting on the surface. Small wooden wells should then be used. This, of course, is more expensive.

The vegetables grown by this system are particularly excellent if the right quantity of water is applied, which experience alone can teach. I have seldom seen any so good, and the consumers need have no fear of being injured by them.

It would be very difficult for anyone to prove that the sewage-liquid, after having passed through five feet deep of earth, with a growing crop on the surface, is on coming out at the exit of the deep land-drains underneath in such a condition as to afford grounds for an action of nuisance raised by any owner of property at a lower level. If the irrigation-works are carefully executed I should not be afraid of risking this; but at the same time, if the levels of the irrigated land admit of the arrangement, I should be inclined to bring the underground water a second time to the surface and send it again in the summer time through the same process upon similar principles. Such an operation should only be done on light sandy land, where any water running over the surface and entirely under control is beneficial.

The amount of dilution enters into this part of the question, and the advantages are on the side of

diminishing the quantity of water supplied. On this point I am supported by the evidence of Sir Joseph Paxton before Dr. Brady's Committee.

In selecting land for irrigation the geological structure of the underlying beds must be considered, so that no risk may arise of contaminating any well-water.

It is possible that at some time the sewage-water might accidentally pass down rapidly through holes made by rats, rabbits, or moles, into a fracture or the general bed of the strata, and so pass into a well, to the injury of the water. It is essential to keep this in mind on the chalk, oolite, greensand and other porous rocks.

For the same reasons, if the underground drainage-water of any piece of land is to be utilized for domestic purposes immediately on its exit from the main-drain, I should prefer taking other land for sewage irrigation; as it is not advisable to run any risk of impure water, which would soon do serious injury.

# CHAPTER V.

## THE DRAINAGE OF TOWNS.

THE system of draining towns at present in practice is to conduct all the sewage into the main-drains, and along with it also all the rainwater off the houses and the washings of the streets.

So long as this is done I believe no satisfactory solution of our sewage difficulties will be found, more especially as the tendency is to increase rather than diminish the consumption of water for household purposes.

The general supply of water in towns is about twenty-five gallons for each person daily. The greater part of this finds its way into the drains, and if even this could be maintained regularly there would be some hope of the sewage being strong enough and sufficiently free from other matters to warrant attempts under most cases to utilize it.

If a question of profit and loss is alone to be studied, then except when gravitation will accomplish the whole process, all machinery and mechanical

details must be planned very economically, so as to make the whole pay an adequate return upon the outlay.

All the calculations and arrangements made for the state of matters existing in dry weather would be completely upset during the first heavy rains, or indeed when any rain fell. The mud from the streets then passes into the sewers along with the sewage, and as the two travel along, the friction of the former along the bottom and sides of the drain rubs down and disperses all the solid parts of the latter.

The valuable qualities of the sewage are then entirely taken up by the water, but being thus diluted in probably not less than, on an average, 200 gallons per head of the population, they have become quite valueless.

To pump all this quantity up to a higher level for the purposes of irrigation would, in a commercial point of view, be a hazardous experiment.

In support of my own observation and experience I may quote from the Report by the Jury for the National Exhibition of 1862 on "Chemical Products and Processes," p. 59 :—" Again the use of ordinary " rain-diluted sewage to irrigate land, after a costly " trial at Fulham by the Metropolitan Sewage Com- " pany, had to be given up, on account of the extreme

"weakness of the fluid and the heavy pumping costs "involved in its distribution on the land. The "sewer pumped from in this case conveyed, besides "sewage, the water of a small natural streamlet, and "the cost in fuel and charges for raising the dilute "mass exceeded the value of the ammoniacal compound saved."

Where the whole sewage and rainwater will flow by gravitation over land fitted for it, it is, I may say, remunerative; but the system has many disadvantages, and should not be followed in any new works; while gravitation in a country like England, which is generally flat, cannot very often be adopted.

Grass-land under these conditions might as appropriately be called *water-meadows* as sewage-meadows.

It is obvious also that the tanks prepared to filter the supply sent down at the rate of twenty-five gallons a head will be quite inadequate for the larger demands made upon them in heavy rains, and if made to suit the latter condition would not be convenient for the former. I have shown previously that no other form of filter than one constructed upon the upward principle will answer for sewage. On this principle the beds of ashes or burnt earth must be porous enough to allow the water to ascend through them, and yet sufficiently heavy not to be washed away, but to rest

upon the filtering trays. This is easily managed if the current is steady and uniform within certain limits, but floods of rain would upset every arrangement by forcing up the filtering beds, and the whole arrangements would then fail.

The Prince Consort, as I have previously mentioned, first discerned that filtration of sewage was essential, and that such filtration could only be accomplished by an upward process. In attempting to adapt his ideas of these tanks to large public buildings I first found out the great difficulties of dealing with the rainwater. Afterwards, having spent two years in attempting to plan filtering tanks for the main-sewer from a town of six thousand inhabitants and having found it impossible, I came to the conclusion—notwithstanding, I may say, the universal practice to the contrary in this country—that the sewage and rainwater must in all cases, in towns as well as single houses, be kept entirely distinct. Agricultural experience led me to the same conclusion.

The sediment obtained by simple deposition in any tanks used for towns (as these tanks are at present arranged) is in most cases nearly all grit or sand from the streets, which sinks by its greater gravity; hence its little value as manure, much to the surprise of many, who, seeing that it has come out of the sewers,

cannot but believe that it must be full of strength. Anyone who has had experience of the disappointment that follows the dressing of land with pond-cleanings will feel the truth of my remarks: the greater part of the ammonia has, in fact, escaped in the water.

Although many praiseworthy attempts have been made to arrest the valuable qualities when held thus in solution, and to convert them into a marketable commodity which would repay the outlay incurred, all have failed: the uncertainty of the quantity of dilution arising from the mixture of rainwater has been a great difficulty in the way.

The materials employed in these experiments or processes cost more than anyone would give for the product when obtained; and, as far as the best chemists of the present day can guide us, there seems no hope of any other result. Many fallacies have been circulated on this part of the subject by giving the analysis of a ton or any fixed quantity of diluted sewage, and estimating the worth of its ingredients according to the marketable value of guano or some other manure in the state in which these are when ready for application to the land. Such statements, leaving out of calculation the outlay involved in the engineering and other arrangements necessary to make

the sewage of any value at all, only mislead the public. The whole sewage and rainfall are worth nothing unless they can be profitably applied: it is entirely a question of outlay and income.

It appears to me that the earth itself is the great natural deodoriser and purifier appointed to convert the refuse and waste of our population into something that will be useful to mankind, and that to this quarter our first and most earnest inquiries should be directed.

It is constantly said that the rainwater is useful in flushing the sewers. Of course it is better that this supplementary assistance should be given to the household water than that some portions of the drains should not be flushed at all; but the rainwater entirely fails in dry hot weather, especially in the end of the summer, just when it is most wanted; and uncertainties of this kind should always be avoided. Arrangements might be made for allowing a certain quantity of rainwater to pass occasionally into the foul drains, so as to save the water-supply of the town in rainy weather; but the whole must be under perfect control, and it should be water off *roofs*, and not from the *streets*.

This irregularity of the rainfall is evident to everyone who will consult the admirable Tables published annually by Mr. Symons of Camden Town.

From these it appears that while the total rainfall of London, for instance, may be stated at twenty or twenty-two inches on an average of years, the irregularity of this fall is such that in one day in June 1863, $1\frac{1}{2}$ inch, or $\frac{1}{14}$th of the whole annual average, fell in twenty-four hours. In fact, he shows that in 1863, $6\frac{1}{4}$ inches (about the third of the whole annual supply) fell in twelve days.

Even after making all allowances for evaporation, what system of sewage-drainage, filtration, utilization, or pumping-machinery could possibly be efficient and managed economically with such wide limits of variation? Evaporation and absorption during the winter months, as previously pointed out, will have scarcely any effect upon the rainfall in the streets, while during that time the less water that is used for irrigation the better it will be for the land, agriculturally speaking.

No tank could be built large enough to hold the flood during heavy rains. At Rugby—where experiments of irrigation from drainage of the same sort were tried—Mr. Lawes states, in his evidence in 1862, that when heavy rains came they were obliged to let the stream overflow, as they could not use it. This is not perfect; especially as the storm sewage is generally the foulest.

On those twelve days which I have mentioned in

1863 the sewage of London must have been diluted to the amount of 1,000 gallons per head of the population. The thicker-peopled a town is the faster will the rainfall get into the drains, because the roofs discharge it quicker than the streets do, and so the difficulties increase with the population.

Surely it would be much better that every house should flush and ventilate its own drains until they enter the sewers, and then that there should be the means of turning into these main-drains a regulated quantity of flushing water daily, so that a fixed proportion of dilution might be arrived at. If any further proof were needed let anyone read the descriptions given, before Lord Robert Montagu's Committee in 1864, of the vast amount of complicated and expensive arrangements that had to be made for London in order to meet the uncertainties of the rainfall when mixed with the sewage.

On the assumption that the water-supply from the companies of London is twenty-five gallons a day per head of the population, it may be said that we have already the full quantity of water passing into the drains that I should recommend for all purposes, including flushing; but let us consider how these twenty-five gallons are expended, and how to deal with them under a new system.

They are used at present for the following purposes :—

1. Ordinary domestic purposes.
2. Manufactures.
3. Public buildings, baths, &c.
4. Extinction of fires.
5. Cleaning and watering of streets.
6. Supply of fountains, &c.

Only the water under the first and third heads, and perhaps some of the second, need pass into the drains if constructed for sewage alone, and the quantity used for these is from ten or twelve gallons for each person. Three gallons more would be amply sufficient for flushing, if properly managed, in the smaller pipe which would be required under the system I am advocating, as the water would be applied at the most effective points.

Even this quantity might be reduced, I believe, without any bad consequences, by placing a water-meter in each house. Under this arrangement at the outlet of the main-sewer we should have the whole sewage of a town diluted to an unvarying quantity of about fifteen gallons of water per head daily, or nearly the same amount (as I have previously shown) that the Chinese, by long agricultural experience, have found

to be the best for their purposes. We should distribute the whole liquid then by engineering arrangements, while the Chinese employ manual labour; and it is possible that they would dilute it more if their method of distributing it by hand was not too expensive even for them.

In our towns at present the whole twenty-five gallons a day pass into the sewer along with the sewage; but the drains, in order to receive flood or storm-water, are far larger than they would otherwise be, and so the flushing power of this water, besides having grit and sand to remove, has not the same effect which a more concentrated stream would have. Nor is the present flushing power of these twenty-five gallons guided into the drains on any regular principle, so that vast quantities of filth accumulate in dry weather where the water does not reach it.

On this point the evidence of Dr. A. W. Hofmann, before Dr. Brady's Committee, is very strong. He states, in answer to Question 671:—"We made not "fewer than fifteen experiments in different sewers of "London during the summer of 1857; the first one, "as I have already mentioned, made with the sewage "of the Savoy-street Sewer, gave ninety-four grains "(of solid matter by deposition) per gallon, and the "second 111 grains per gallon. Again we examined

" the Savoy-street Sewer after a storm ; there was a " tremendous storm in that summer, which you may " recollect, when on the next morning the sewer was " found to discharge as much as 296 grains per gallon. " It deserves to be remarked that the gaugings of the " sewer at that time showed that the amount of " sewage discharged was at least six times the amount " delivered under ordinary circumstances, but not- " withstanding this extraordinary dilution the sewage " contained as much as 296 grains per gallon. We " attributed this enormous quantity to the amount of " muddy matter deposited in the sewer disturbed by " the current, and considered it to be quite an excep- " tional case."

During that storm eighteen times more the amount of deposit must have come down than what did during the previous dry weather. Dr. Hofmann further states that the Fleet Sewer before rain gave 74 grains per gallon, after rain 208 grains per gallon; and all the other sewers which he experimented presented similar results.

A considerable part of these grains was road-grit; but in answer to Question 672 he states, as the results of his experiments, that " out of 100 grains you may " say, roughly, that forty are valuable and sixty are " simply ballast." The forty valuable grains are of course those containing the fertilising qualities of the

sewage; so that it appears almost conclusive that during dry weather there must be an accumulation of fœtid matter which the present system of flushing does not and never can properly remove, and which remains putrefying under ground.

Dr. Hofmann's statement of forty grains of solid ingredient and sixty grains of ballast is open to further investigation. My own impression is that he has overstated the quantity of valuable matter present, and it is of importance to ascertain whether that proportion of 40 and 60 prevails in dry summer weather or during heavy rains. He states that he formed his opinion upon samples collected during "average weather" extending over about three summer months. As the rainfall is not given during these three months, no perfectly accurate inference can be drawn in favour of the views I have advanced; but the margin is so large that the probabilities are strongly in favour of the opinion, viz., that a great quantity of fæcal matter is retained in summer for a long period in the sewers as they are constructed at present, until the rainwater comes, stirs it up, and cleans it out.

In Froude's History of England (vol. vii. p. 519), speaking of the plague in London in 1563, he states :—
"In July the deaths in London had been 200 a week;

"through the following month they rose swiftly to "700, 800, 1,000, and in the last week of the month "to 2,000; and at that rate, with scarcely a diminu-"tion, they continued to die till the November rains "washed the sewers and kennels clean, and the fury "of the disorder was spent."

How could such an emergency as that be met by the present system, with its irregularities, its openings in the streets, and its large area under the surface for generating foul air?*

In the new system of drainage for London some of these evils will be remedied, especially by making provision for the heaviest storm-water; but the greater part of the rainfall is to pass along with the sewage, and this appears to me an imperfect system, and in some respects an insurmountable difficulty in the way of any scheme for thoroughly and economically

* In corroboration of this, see a leading article in the "Times" of 10th December 1864, where it is shown that the dry season of 1864 has been remarkably unhealthy, while that of 1860, which was wet, was the contrary; and thus we are still relying, as they were in 1563, upon the uncertain autumn rains to flush the drains. See also the Mortality Bills for the Metropolis published in the "Times" of 11th January 1865. In speaking of the thirteen weeks to Christmas 1864, which were excessively dry, and so the drains were foul, occurs the following passage:—"1064 persons "have died from typhus—which shows a large increase as compared with the "corresponding quarters in the years 1860–63, the deaths of these periods "amounting to 311, 624, 796, and 881. The alarming inroads made by this "disease on the lives of the population deserves careful investigation, and shows "the necessity of carrying out at once every available sanitary measure."

utilizing the sewage. In all other towns with which I am acquainted, the rain and storm-water drains are connected with those for the sewage.

Under a more complete arrangement an order would be given on the first outbreak of disease to flush the sewers from every house and every street, and the whole sewage would be swept clean out every day, while the ventilating shafts overhead would carry off any noxious vapours out of reach of the inhabitants.

The basins of fountains might be used for flushing purposes.

Besides, for sanitary reasons, it will be found that nearly all the foul smells in towns in hot dry weather come into the streets through the openings which let down the rainwater.* Any gentleman who will examine his stableyard will find the same thing. These rainwater receivers are scarcely ever trapped, and cannot well be, as the water in the traps evaporates from the heat of the sun and other causes.

This is important in a medical light. Those who reside in towns—and, indeed, all people—are exhausted by the heat of summer, and in the autumn become predisposed to fever, cholera, and many similar diseases which are both fostered and rendered

* No one could walk the streets of London or any other town during the dry summer of 1864 without perceiving the truth of my statements.

malignant by effluvia from the sewage. During the winter and spring months rain falls, however, more regularly than it does in the latter part of the summer and autumn, and when it goes with the sewage does its proposed work of periodical flushing more effectually. In the summer of 1864 we had no rain worthy of mention from the middle of May to the end of September.

Further, during summer, a considerable portion of the twenty-five gallons a day supplied per head from the water-companies, as previously mentioned, escapes by evaporation, while we have always in the months from June to October long-continued tracts of dry hot weather, with rain on fewer days, although heavier while it lasts; so that during that period of the year when the human frame most requires a healthy atmosphere the drains of towns, as at present constructed, are in the worst state for accumulating filth under-ground, from which the gas, attracted by the warm temperature, comes up through the gratings in the streets.

I am aware that charcoal is largely used to arrest the foul air arising out of the street-drains, and that it answers well to a certain extent; but it would surely be a safer and better process if these air-filters over the street-gratings could be dispensed with altogether, as it is always more prudent to prevent an evil than to pursue and counteract its effects afterwards.

On this point Dr. Hofmann, in his report on Disinfectants for the Exhibition of 1862, says :—" It is " indisputable that the preponderance of opinion is in " this country year by year inclining towards *radical* " measures of sanitary reform, as more effective and, in " the long run, more economical than *palliative* ex" pedients. In other words, the continuous removal of " putrescible filth from town to country *before putre" faction has had time to set in* is, on the whole, " deemed preferable by the English to the detention " of filth in its accustomed receptacles, coupled with " the use of disinfectants to prevent its putrefaction or " to arrest it when begun."*

It is also essential to observe that these water-gratings in the streets allow the gas to escape at the worst point at which it could come—viz. at the feet, so to speak, of the inhabitants, whence it passes upwards through the air they breathe. It may be much diluted in the open air, but in some close crowded quarter it becomes concentrated, and malignant disease is the result.

It would surely be much safer to multiply the ventilating pipes of each house and carry the foul air

* Probably Dr. Hofmann aimed these remarks more especially at cesspools, but they are equally applicable to the present system of town drainage, which I believe I have shown to be little better than a cesspool elongated.

away high overhead, and thus provide sufficient outlets, while special furnaces, as ventilating shafts, might be added in the great public drains. I wish it, however, distinctly to be understood that, without ample ventilation and flushing water, a separate system of drainage for sewage alone will not work efficiently: without these two essential details it would fail in every respect.

As under the present system some parts of the sewage must be stagnant for weeks during dry weather in summer and autumn, and thus give off deadly gases, the sewage-drains, under the scheme I am desirous of recommending, would be flushed daily if necessary, while no gas would escape from them into the streets; and any foul air in the drains would, as I have already pointed out, be much less in quantity and of a less hurtful character.* In towns, as with dwelling-houses, the rainwater drains can be allowed to discharge at any point without injury to health, so that I believe the compensating advantage of shorter drains for flood-water thus obtained would make the new system probably as cheap in the first instance as the older one.

* Under the system I am advocating, also all necessity for man holes, storm outlets, ventilating holes in the streets, gullies, &c., into the foul drains which can never be air tight, would be done away with.

Even if it should turn out to be dearer, the advantages that would arise would compensate for the outlay; as there would then be hope of utilizing the sewage in almost every case; and, besides, a remedy could be found for the injury done to the rivers and the country generally; matters upon which a money value can scarcely be placed. Who can estimate the injury done to the Thames, for instance?

My opinion, therefore, is that the London rainfall and the water off the streets should have been conducted straight into the Thames, and that the new system of drainage should have received the sewage alone and conveyed it to places beyond the limits of the metropolis.

For the system I have described, the old drains or some modification of them, discharging as they did into the Thames, would have sufficed, if retained, for the rainwater; while the new ones, for the sewage alone, might have been much smaller in size, and all the pumping-machinery and other arrangements would have been reduced in proportion. In his evidence before the Select Committee on Sewage (Metropolis) in 1864, Mr. Bazalgette, the engineer, states, in answer to Question 5,186:—"On all ordinary occasions, for "say sixteen hours out of the twenty-four, we shall "have working at the Abbey Mills Station one engine

"of 197-horse-power, working slowly, taking the "sewage, and then, during the eight hours of the "maximum flow, we shall increase that working up to "394-horse-power; but on occasions of heavy rains we "shall have to lift 13,400 cubic feet, and shall work up "to 910-horse-power, and we propose to provide at "that station 1,140-horse-power." This may be taken as a specimen of the expense involved in pumping rainfall, which might have gone of itself into the river.

I feel satisfied that the utilization of the sewage would then have been well worthy of consideration on economical grounds, setting aside the preservation of the purity of the river, although that portion of the subject deserves serious attention.

As the matter stands at present I believe the utilization of London sewage upon a perfect scheme to be hopeless, if any adequate return is to be obtained for the outlay necessary to make either the solid or liquid parts available.

Taking as a base of calculation the metropolitan area at 100 square miles, and the annual rainfall at twenty inches, we should have, if the rain fell daily, seventy-five millions of gallons each day to provide for, besides the same quantity supplied for all purposes by the water-companies.

This state of matters scarcely ever happens, how-

ever, from the uncertainty of the rain. My proposal is to reduce the quantity of foul water with which we must deal to a fixed daily delivery of, at the outside, thirty to fifty millions of gallons; the town would be healthier, and there would be a likelihood of converting the sewage to some benefit to the country.

As I have not examined the country round London I am not prepared to say that there is sufficient land suitable for the purpose to warrant a system of irrigation, even upon the principles I have advocated, being undertaken on economical principles alone. It would require a very long investigation, as well as serious thought; but I believe it would be a waste of time to go into the matter unless a complete change is made in the system of town-drainage.

I have selected London especially for illustrating these points, because more information can be obtained about it than about any other town in the country. If the present uncertainty and excessive dilution exist in London, where the rainfall annually averages from twenty to twenty-four inches, and which is thus one of the driest towns in the country, the difficulties are immensely increased with places such as those in Lancashire, where the rainfall is annually about twice as great. In most other towns

the same principles have been acted upon, and are equally objectionable.

Frequently also towns are drained into the nearest stream, and when flood-waters come the solid parts of the sewage float upon the top and are spread all over the surrounding country. This is another reason why the sewage should be kept by itself and filtered.

Opposite to this page is a sketch showing what I think the general system of double drainage for a town should be.

In a suburban or mixed town and country district there are at present generally two or three cesspools on each property, and the overflow is conducted into the nearest ditch, leading to endless nuisances, and great danger of pestilence in hot or dry weather. When ditches are full of water the danger is not so great as when they are empty, as the mud impregnated with sewage-matter begins then to ferment. The dry season of 1864 has brought this evil in many villages so prominently before our notice that something must be done.

As each proprietor may wish to utilize the sewage and coal-ashes upon his own place, and have the power occasionally of using the liquid overflow, I have made a further sketch opposite page 69, showing how this may be done so that all the liquid not required

would be conveyed to some spot where it could be turned into a grass-field or a market-garden.

The waste in this country of valuable material by the prevalent system of managing sewage is indeed marvellous, even if nothing be said of the injury done to our finest rivers. Take, for instance, the Thames above London, with which I am best acquainted. Every town along its line empties its sewers into the stream; and as cesspools are very properly being done away with on sanitary grounds while the population is increasing along its banks, the loveliest of our rivers is fast becoming little better than a great foul sewer. It has been for centuries the favourite resort of the inhabitants, but it will daily become more offensive and deserted. Already, in consequence of what has been done during the last ten or fifteen years, there is a tract of about two miles by the riverside near every town which in the heat of summer or after a flood is shunned by everyone. What will this come to if it is not arrested?*

* In the first week of November 1864, when the Thames was lower than it had been for many years, I had occasion to examine the bed of the river at the mouth of a sewer discharging its contents from a town of six thousand inhabitants. I found that opposite the mouth of the large drain an immense bank of the most putrid mud and filth had formed, fully five feet deep in some places, stretching across into the stream. When this was stirred up and sent into the current, which had to be done to clear the mouth of the drain, the stench was intolerable. For a mile down the river a thick grey slimy

Is a great main-sewer to be constructed along the banks for a hundred miles, from Oxford to London, and the whole sewage and rainfall to be taken to Erith, to be pumped up and emptied into the sea? The present system of town-drainage leads us ultimately to this conclusion. I can foresee no other result in the long run than that, instead of being the delight of all, the river will become so contaminated as to be unbearable.

The Thames is also the source of the great supply of drinking-water for London and other towns, but, although it is filtered before use, is the idea a pleasant one that the whole filth of the population from Oxford to Kingston has been emptied into it?

From the Thames no less than five London water-

deposit lay upon every bank, and every twig and weed in the stream was covered with it. In the eddies, where the water was quiet, a thin blue and yellowish green scum was swimming on the top, and the solid parts of the sewage recently deposited might be seen floating four miles from the town. If any of that water had been used for domestic purposes it is almost certain that, if fever had not been caused by it, a weakly general state of health would have followed, which opens the door to other diseases; especially in the fall of the year, when from other causes the constitution is liable to such attacks. At the point I examined it the stream was flowing with a steady current of four miles an hour, and it occurred to me, if this great deposit of filth has accumulated from so small a town on that stream, was it not quite certain that a huge delta of putrid mud would form at the mouth of the great London sewers, where, according to the best information I can receive, owing to the rise and fall of the tide at Barking Creek, the current only sets one mile towards the sea in the twenty-four hours? And if so, would not such a putrid mass be certain to originate and spread disease?

companies draw their supply. Sewage impurities cannot be thoroughly taken out by filtration, and tainted water is a fertile cause of disease: cholera and fever especially are the general results of drinking water derived from such a source.

Judging from my own experience—which is confirmed by that of others—no mechanical or chemical means have yet been discovered by which sewage-water can be so thoroughly purified as to be perfectly safe for domestic purposes. The roots of living plants possess some subtle powers of appropriation which alone seem to accomplish this purpose.

It must also be recollected that the rivers in England are almost all sluggish, so that the filth readily becomes stagnant in them.

It appears to me that the course I have attempted to describe is the only one, as far as our present knowledge extends, by which the evils can be remedied, keeping before us both the sanitary and economical principles involved, and also remembering that the feelings of the people in this country are too strongly in favour of the watercloset system to be set aside. I have never yet seen a building of any description, or a town, where the greater part if not the whole of this scheme could not by some means be carried out.

# CHAPTER VI.

## THE ARTERIAL DRAINAGE OF THE COUNTRY.

THE compulsory utilization of sewage by towns will almost of necessity lead the way to another series of national improvements equally deserving of attention.

There is a strong feeling in the country that before many years have elapsed a general Act must be passed through Parliament for regulating the arterial drainage of the kingdom, and making provision for the deepening, widening, embanking, and straightening of rivers, and the abolition of mills and weirs which dam back the water in the valleys.

As an example of these watercourses I cannot take a better illustration than that of the River Blackwater in its course from Aldershot to and below Sandhurst. The whole subsoil of the valley through which this part of the river flows is more or less a tenacious clay of the middle Bagshot Beds. The high hills surrounding it on all sides send down into the valley great quantities of water, which flood the whole land upon the lower levels.

The bed of the stream itself is very shallow,

winding in every direction, and half-choked up by alders, which grow upon its banks and send their roots across, so that everything brought down by heavy floods is arrested and sends the water out into the fields. To add to the natural difficulties there is a mill at Yately, which shuts back six or seven feet of fall, to the detriment of all the higher lands.

The effect of the whole is that, up the valley from Yately to Aldershot, there are thousands of acres which have water lying permanently under the surface at a foot deep, and can never be drained or improved in any way. Their value and productiveness are not one-half or one-third of what they might be; while to this, must be added other evils of fogs, damp, and malaria. The whole of the best agricultural land lies in this valley, containing as it does the accumulation of the vegetation of centuries; and I believe that if it could be drained and floods prevented, the increased value of the land would in two or three years pay the fee-simple of the mill and all the outlay necessary for completing so desirable an undertaking.

Since railways have brought coals so cheaply into every locality the necessity of these watermills has diminished, and steam-power would in every respect be far more beneficial for the whole community.

The same remark applies to the weirs and locks in rivers where such have been made for internal navigation. But as the land in these valleys belongs to many different proprietors, who will never move—and, indeed, practically cannot move—independently in the matter, a central authority, acting under Parliamentary powers, must be constituted to direct and control this business and simplify the proceedings, with power to compensate all existing rights of mills, &c., and to levy a tax, either annually or by instalments, upon the lands benefited by the improvement of the watercourses.

Almost all the valleys in England are in a similar state, and a Bill granting such powers would, I believe, be generally acceptable to the country: its own intrinsic merits would carry it. By way of objection it could but be urged that it might destroy the picturesqueness of the winding streams, but there would still remain enough of that kind of beauty; and the same argument would apply to the retention of any uncultivated wild swamp or barren heath, while in this thickly-peopled country what is useful must generally take precedence of that which is unprofitably barren and unhealthy.

Whatever authority is constituted to manage the arterial drainage of the country must have power to deal with the whole watershed of any river from its

source to its mouth, and any such extensive scheme of drainage must commence at the lower levels of the river. If the upper portions of a river are remedied first, and independently of the lower, the effect must be that the rainfall will come down from the higher grounds more rapidly, and flood the lower worse than before.

Floods are caused by the sudden rushing down of such water as cannot be absorbed by the soil, and the cutting of *surface* drains increases this tendency. *Deep underground or agricultural* drainage, however, moderates these floods, and from the confusion of "surface" and "underground" drainage, and by speaking of them as if they were the same thing, has arisen the erroneous opinion that the great amount of what is called "the *drainage*" in the country has increased the flooding of the rivers.

When land is undrained and naturally full of water, this water in the land either rises by compression from some bed below the surface, or is the result of rainfall when unable to find any underground outlet. The land therefore soon absorbs all that it can contain; and all the rainfall, except that which escapes by evaporation, rushes off the surface. When the land is thoroughly underdrained, however, a porous sponge of earth is formed, which slowly

admits the rain, and by the resistance offered to it in its downward passage moderates the pace of the water as it travels to the lower levels, so that what the plants do not require is gradually and over a long period discharged at the outlet of the main-drain. If this be not the case, whence comes it that in almost all clay land, when underdrained, the main-drains continue to discharge long after the rain has ceased?

Even if we set aside all the sanitary and agricultural aspects of the question, the effect which a system of general arterial drainage, followed by a regular underdrainage of the valleys adjoining, must produce upon the rivers, would be to afford, by the diminution of floods, a more regular and longer-continued store of pure water in summer and autumn, and thus yield a better supply for domestic use in towns.

The total amount of evaporation from the fields during the year would be less, and the total amount of water discharged into the rivers greater and purer, and being more uniform would be more beneficial. I greatly doubt, however, if the effect of any agricultural drainage would be appreciable in any marked degree upon such rivers as the Thames, in so far as the water-supply of the towns along its banks is concerned.

Without such a measure of arterial drainage the sewage of many important towns could not be satisfactorily utilized, for the following reasons.

As I have stated in a former part of this work, the most profitable and beneficial method of utilizing sewage is by conducting the filtered liquid to land by gravitation, while the irrigation of any land naturally damp, unless that land had been thoroughly underdrained at four or five feet deep, must necessarily lead to imperfection or failure.

As a further illustration of the manner in which these two principles affect each other, I may refer to any of the rapidly-rising towns on the Blackwater River. At present their sewage arrangements are very incomplete. Every house has a cesspool, and the nearest ditch is used for the overflow, except where the gravel-beds upon which the houses are built absorb the sewage-water, to the certainty of contaminating the wells; but a general revision of the drainage must inevitably follow before long, and if it be not discharged into the river the only practicable spot for utilizing the sewage by gravitation is on the meadows adjoining the Blackwater. But it is at present impossible to drain these meadows, owing to causes which I have already described; and, unless a general Arterial Drainage Act clears the way, it would be imprudent to attempt

the process on the best system, and either steam must be used to pump the liquid up or some other alternative adopted, with less chance of success and at greater cost.

The same difficulties occurring in many towns which I have cursorily examined have impressed upon me the conviction that the two measures must go hand-in-hand to accomplish the greatest amount of public good.

# CHAPTER VII.

## GENERAL SUMMARY.

Great difficulties, arising from several causes, have hitherto stood in the way of Corporations of towns or Boards of Guardians acting for parishes, if they desired to utilize their sewage. Of these the chief has been that no really practical method of doing so in all cases has yet been brought before the public, and that these corporations or boards either had not, or hesitated to exercise, the power of purchasing land and taking the necessary steps for carrying out some process of utilization. Corporations have generally contented themselves with ridding the towns of the filth, and discharging it at the nearest outlet at which they could do so unchallenged by anyone. At the same time the proprietors of the land adjoining any ditch or stream which received town-sewage and rainwater, or the general land-drainage of the country, have frequently found themselves totally unable to overcome the engineering difficulties of an ever-varying stream in making the whole manageable on economical grounds.

These owners of land have no power to make the towns alter their system of drainage, and not yet having seen the exact causes of the engineering difficulties have given up the attempt as almost hopeless. It would therefore be much out of place to blame the corporations of towns for not having done more than they have; in fact, they have been most ready to do all in their power for the advancement of sanitary science.

Neither should the agricultural community be blamed for not having been more ready to utilize the sewage: it has never yet come to them in such a shape as to enable them to do anything with it. Any farmer would be perfectly right in refusing to have the sewage of London sent down upon his land at all seasons, as it is at present, with its gravel and sand and irregular water-supply. Especially if his land is clay or marsh and level, the damage done in wet weather and winter, if he was compelled to receive the liquid, would generally overbalance the benefit he would receive in summer.

To remedy these matters the towns should have power to purchase land which could be proved to be adapted for irrigation, and the inhabitants of the towns to be benefited should be charged with interest on the outlay and receive the benefit of any return from the process. It would be absurd to pass a

law preventing towns from discharging their sewage into the rivers, and forcing them to utilize it upon land, unless power is also given to the towns, or to some one, to compel the sale at reasonable prices of that portion of land which was necessary for the purpose.

A Permissive Bill would, in all probability, end in nothing. The people of this country are now so much interested in this question that they would readily submit to some compulsory law of this description, and in a short time, as the results became apparent, would heartily assist in carrying it out, if an improved system of drainage and the utilization, which must go together, can once be shown in successful action. If something of this sort is not done every town will go on as heretofore, wasting its sewage and sending the solid and liquid parts into the nearest rivers and the gaseous parts into the air, and lawsuits, nuisances, and diseases will be the result.

If even the filtration of the sewage before it is emptied into the rivers were ensured, and this, when the rainwater is excluded, is thoroughly practicable, the gain would be great: and I need scarcely call attention to the filthy condition of the sea-shore in the neighbourhood of the main-drains of our favourite bathing-towns.

If I have been successful in pointing out an improved course of procedure in this difficult subject it will, I think, be admitted that the whole scheme is harmonious and coherent. I have sought to show that, when properly carried out, the conveying sewage by suspension in water is the cleanliest and probably the cheapest for the occupants of buildings, and the most beneficial for utilization in the country; that all the portions of houses set aside for closets and foul water should be on the cold or north side; that the families should live on the warmest side; that from a sanitary point of view both these arrangements are best; that there is no better filtering or mixing material than house-ashes, which are always abundant in the neighbourhood of human dwellings; that the filtering process, which simplifies the application of the liquid overflow, separates the solid matter, which can so much more easily be removed into the interior of the country, where the want of manure is every day more felt; while the filtered liquid, which is much less portable, can be applied more beneficially near the towns; that there is no better purpose to which this liquid can be applied than growing grass and vegetables, and that these are the most desirable crops to obtain; that the kind of grass grown with this liquid is best adapted for milch-cows,

which again are so valuable near a town; that the exclusion of the rainwater from the sewage-drains is healthiest for the towns and essential to the perfect utilization of the sewage in the fields; and also that, as many of our towns now draw great part of their water-supply from the rivers, the rainwater of the lands lying in the upper portions of those rivers should be allowed to pass into the stream unpolluted by a mixture of what is not only nauseous but very injurious to health.

The conditions under which the consideration of all these points, as well as of the arterial drainage of the rivers, is forced upon us, justify the hope that the whole subject may now be taken up with goodwill and with a fair prospect of success.

Underground drainage has become quite matured in practice, and is the first and essential preparation of the soil for surface treatment. When gravitation cannot accomplish the process of irrigation, steam-engines have come to our assistance for pumping purposes as a cheap and certain agent, and steam has also done away with the advantages or the need of watermills, which help to flood the richer land in the valleys; while, again, this flooded land in the valleys, if drained, would grow the finest grass, and good grass is now doubly valuable.

The development of railways has in most places rendered unnecessary those weirs and obstructions on rivers which have been erected in former days for the benefit of inland navigation. Pure air and pure water for the preservation of health are every day becoming more impressed upon the community as a safer system than trusting to the efficacy of medicine in curing diseases generated by either intentional or accidental neglect of the conditions essential to health.

Looking to these considerations, we must surely admit that the course to be followed is no longer a matter of doubt or discussion,—that the time has come to go to work in earnest, and that the whole of this subject, not less than the Smoke Prevention Bill, the Chemical Nuisances Bill, with many others of a similar class, deserves to be dealt with not as a Local but as a great National Question.

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